U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: RECOMMENDED METHOD FOR FAA APPROVAL OF AIRCRAFT FIRE EXTINGUISHING SYSTEM COMPONENTS

Date: 9/22/00 **AC No: 20-144**
Initiated by: ANM-100

1. PURPOSE. This advisory circular (AC) provides guidance on the various aspects that should be considered in the FAA approval process of fire extinguishing system components manufactured under a Production Certificate (PC), components to be FAA approved under the Part Manufacturer Approval (PMA) process, or design changes to components originally approved by either method. This AC does not constitute a regulation, however, it provides a method, but not the only method, for obtaining approval of aircraft fire extinguishing system components. This is intended to enhance the standardization of all FAA Aircraft Certification Offices (ACO) and Manufacturing Inspection District Offices (MIDO) in the approval process of the critical components of an aircraft fire extinguishing system.

2. RELATED FAR SECTIONS.

Title 14 of the Code of Federal Regulations:

Part 21	Subpart G & K.
Part 23	§§ 23.1195, 23.1197, 23.1199, 23.1201, and 23.1301.
Part 25	§§ 25.851, 25.855, 25.857, 25.901, 25.1195, 25.1197, 25.1199, 25.1201, and 25.1301.
Part 27	§§ 27.859 and 27.1301.
Part 29	§§ 29.851, 29.859, 29.1195, 29.1197, 29.1199, 29.1201, and 29.1301.

3. RELATED READING MATERIAL.

MIL-I-23659C	Military Specification - Initiators, Electrical, General Design Specifications for, dated 4-24-87.

MIL-STD-1576 Military Standard – Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, dated 7-3 l-84.

MIL-C-22284A (AS) Military Specification – Container, Aircraft Fire Extinguishing System, Bromotrifluoromethane, CF3BR, dated 9-18-96 (Notice 1)

RTCA/DO-160D Environmental Conditions and Text Procedures for Airborne Equipment, dated 7-29-97

FAA Order 8 110.42A Parts Manufacturer Approval Procedures, dated 3-3 l-99.

FAA Order 8 120.10A Suspected Unapproved Parts Program, dated 4/97.

4. DEFINITIONS. For the purpose of this AC, the following definitions apply:

Production Approval Holder (PAH). The holder of a production certificate (PC), approved production inspection system (APIS), Parts Manufacturer Approval (PMA), or Technical Standard Order Authorization (TSOA), who controls the design and quality of a product or part thereof.

Firex. Fire extinguishing system which consists of the agent container and all attached components.

Cartridge. Device used for discharging pressurized extinguishing agent.

Burst Disc. Diaphragm that ruptures to allow agent to escape.

Fill/Charge Fitting. Device to fill container and may serve as the pressure relief.

Pressure Indicator, Device to indicate pressure or status of pressure vessel.

Discharge Head. Device that houses cartridges and interfaces between the pressure vessel and the agent distribution system.

Initiator. See “Cartridge” above.

5. SCOPE. A fire extinguishing system is comprised of many components which are critical for the proper operation of a system as installed in an aircraft. The 14 CFR 25.90 1 (b)(2) requires that components of the installation must be constructed, arranged, and installed so as to ensure their continued safe operation between normal inspections and overhauls. The applicant should evaluate the fire extinguishing system and establish minimum reliability standards for the components of the system so that the overall system can meet this requirement. The components should be designed and qualified to

meet specific operating performance, service life and reliability requirements of the fire suppression system design established at the time of type design approval. It is recommended that Production Approval Holders (PAH) and Parts Manufacturer Approval (PMA) applicants demonstrate that their candidate components meet or exceed these criteria. This document describes the critical parameters involved with the design, production and testing of the following components: Explosive firing cartridge, precision burst disc, fill fitting, pressure indicator and discharge head. This AC does not address the complete aircraft system installation. There may be airframe installation requirements and boundary conditions that should be met prior to installation approval.

6. BACKGROUND (FIREX SYSTEM FUNCTIONAL OVERVIEW). There are generally three cartridge activated firex systems onboard commercial aircraft. These systems provide fire extinguishment for engines, auxiliary power units (APU) and cargo bay compartments. The extinguishing agent is contained in a pressurized vessel that is sealed with a precision burst disc. A discharge head containing a cartridge and strainer is attached to the pressure vessel. When a tire is detected, the firex system is activated by applying an electrical firing pulse to the cartridge. The aircraft electrical system supplies the firing pulse, and the agent is discharged into the fire zone through a distribution system of piping and nozzles.

Most firex systems are designed to use a detonating type cartridge. In some types, when the firex cartridge is detonated it produces a controlled shock wave that fractures the burst disc on the pressurized container, allowing the agent to escape. In other types, the firex cartridge utilizes a slug that, upon detonation, penetrates the burst disc, thereby discharging the agent, or supplies a pressurizing force to drive a piston which in turn moves a cutter knife, hence piercing the burst disc and allowing the agent to escape. The opening in the burst disc is dependent on the application - high rate discharge (engine/APU) or a combination of high rate and continuing concentration (cargo). In either case, the opening of the burst disc diaphragm should meet critical performance characteristics. A proper size opening should ensure the correct flow rate of agent to the desired destination. A system of diverter valves/filters may be used to control where the agent travels for some cargo applications, and diverter valve/filter inspections are normally accomplished to ensure clearance of debris after discharge.

7. FIREX CARTRIDGE.

a. General. A firex cartridge is an explosive component of an aircraft fire suppression safety system. Firex cartridges are specifically designed and qualified to meet the specific operating performance, service life and reliability requirements of aircraft fire suppression system designs. Parameters for the design, production, testing, approval process and methods for demonstrating compliance to system requirements are covered in this section.

b. Design Parameters.

(1) Physical Parameters. These attributes include all information related to how the cartridge interfaces with the aircraft firex system. These include, but are not limited to the following:

(a) Length dimensions (e.g., threads, output cup, overall, connector).

(b) Diameter dimensions (e.g., threads, output cup).

(c) Concentricity of dimensions.

(d) Tolerances.

(e) Thread size.

(f) Thread type.

(g) Electrical connector specification.

(h) Mounting features (e.g., relationship of cartridge output cup to pressure vessel burst disc.).

(2) Electrical Parameters. These parameters include the electrical stimulus required to properly and reliably initiate the cartridge. Of equal importance are the electrical requirements that ensure the cartridge will not inadvertently fire. The cartridge electrical parameters should be compatible with the applicable aircraft electrical system requirements, limitations, and tolerances. A list of the electrical parameters are:

(a) Minimum Firing Current*. The minimum firing current required to reliably initiate the device should be established. This is typically expressed with a current level and a time duration such as 3.5 ampere pulse for 10 to 50 milliseconds.

(b) Firing Circuit*. Each type of cartridge has a different firing circuit. The type and number of circuits are related to the connector specified for the particular aircraft. The identification and proper orientation of the pins on the cartridge is critical for correct functioning of the firex system. The circuit diagram identifies each pin on the cartridge typically by a letter or number. In addition, the circuit resistance should be specified: typically 1 .O ohm for each unit.

(c) No-Fire Current*. The current at which the device will not fire nor degrade: typically a minimum of 1 amp or 1 watt for five minutes.

(d) Electrostatic Discharge*. The cartridge should not fire when exposed to an electrostatic discharge pulse. The electrostatic discharge is typically 25000 volts from a 500 picofarad capacitor thru a 5000 ohm resistor shorted pin(s) to case.

(e) Electromagnetic Interference (EMI). RTCA/DO-160 should be used as a standard and limitations on the aircraft should be determined. The cartridge should not fire when exposed to various electromagnetic fields. The types of fields specified are generally produced from radar and communication systems. Electromagnetic interference protection criteria should be established based on aircraft system EM1 limitations.

(f) Insulation Resistance/Dielectric Withstanding Voltage*, Insulation resistance of typically 100 megohms at 500 volts DC should be used to prevent the loss of a fire pulse due to internal shorting or arcing.

(g) Dielectric*. The cartridge should typically have a dielectric strength of 1000 volts AC RMS shorted pin-to-case and leakage rate should not be greater than 0.1 milliamps for 60 seconds.

(* The values may be dependent on the installation requirements).

(3) Functional Parameters. Upon initiation, the cartridge should provide sufficient energy to effectively open the burst disc but not enough energy to cause a failure of the firex system, or aircraft.

(a) Installed Air Gap. The distance between the end of the cartridge and the surface of the rupture disc. The installed air gap with the approved burst disc(s) should be established with respect to all system installation variables and tolerances, and with repair limits for the bottle burst disc assembly accounted for to determine the minimum and maximum gap conditions. The minimum and maximum gap should be used for system level testing.

(b) Burst Disc Opening. The opening size of the burst disc should be identified for the applicable installations and is a critical performance characteristic. The proper size opening should be evaluated to ensure the adequate flow rate of agent gas to the desired destination. The size of the required opening may be different for engine/APU versus cargo compartment installations. Burst disc opening should be established with the pyrotechnic charge and electrical energy specifications at their minimum tolerance, and the minimum and maximum temperatures established for the system. This disc opening should be equal to or greater than the minimum flow area of the discharge head. It is essential that an adequate margin of safety be established.

(4) Environmental Parameters. The cartridge should function normally after exposure to all the following elements. (A description of most of these environments can be found in RTCA DO- 160, or equivalent specifications.)

(a) High temperature (200°F)*.

(b) Low temperature (-65°F)*.

(c) Temperature shock/Humidity/Altitude Cycling*.

(d) Vibration*.

(e) Shock*.

(f) Drop test (6 feet).

(g) Drop test (40 feet**).

* The values can be dependent on the installation requirements,

** The cartridge does not have to function properly after a 40 foot drop, but should remain safe, i.e., not explode.

(5) Cartridge Design

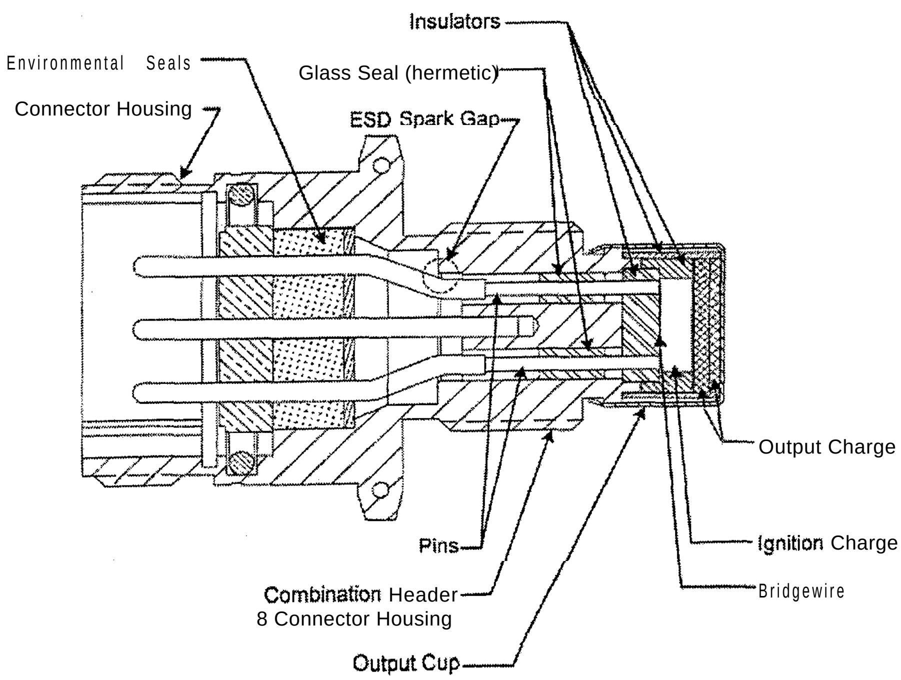

Figure 1. Cross-section View of a Typical Firex Cartridge

(a) Header. The header is typically a stainless steel housing with pins imbedded in a high pressure hermetic seal. The pins provide the electrical connections from the external wiring or connector to the bridgewire. The seal is critical to providing a high pressure hermetic seal before and after firing. It provides:

1 Pressure and shock barrier between the explosive output and the electrical connections.

2 Hermetic moisture seal to protect the explosive charges.

3 Mechanical retention of the pins.

4 Electrical isolation of the pins.

Cracked or poor seals can cause failures because the header pins could be explosively dislodged from the cartridge, resulting in agent leakage through the cartridge backshell. Also, cracked or poor seals can allow moisture to infiltrate and degrade the explosive charges during the environment exposure cycles of aircraft operation. This will degrade performance as well as the effective service life of the cartridge. The method of verifying the integrity of the seal (typically a helium leak test) should be defined by the applicant.

(b) Bridgewire. The bridgewire initiates the detonation by heating the ignition charge to its ignition temperature. The specific bridgewire size and material should be selected to meet the required all-fire and no-fire reliability.

(c) Explosive Charges. The typical cartridge contains a minimum of two types of explosive charges, an ignition charge and an output charge. These charges initiate sequentially in the cartridge to generate the required energy output to rupture the firex system burst disc. The bridgewire initiates the cartridge by heating the ignition charge to its ignition temperature.

1 Ignition Charge. The ignition temperature and thermal conductivity characteristics of the ignition charge have a significant effect on the all-fire and no-fire reliability and performance of the cartridge.

2 Output Charge. When initiated, it provides the energy focused to effectively open the burst disc without causing other damage to the firex system or aircraft.

(d) Cartridge Validation. To validate compliance to the all-fire and no-fire conditions, tests may consist of firing a group or groups of cartridges at various current levels and noting the performance characteristics of the cartridge. Specific quantities of specimen for testing should be established to be statistically significant and provide the desired confidence levels. The current levels should be statistically selected and the results analyzed to provide no-fire and all-fire current ratings at various required reliability and confidence levels (0.99 reliability at 95% confidence per Table 1).

(e) Basic Qualification. It is recommended that each cartridge design be qualified to meet and address the items of the following matrix. Military Specification MIL-I-23659C provides details on how these items should be addressed.

Table 1. Engineering Design Test Schedule

TEST	REF. PARA. *	NUMBER OF INITIATORS (GROUPS)																			TOTAL
		6	6	20	20	20	20	20	20	20	20	2	2	2	2	2	2	2	2	2	190
Dielectric withstanding Voltage	4.4.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	190
Radiographic	4.1.3.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	190
Leakage	4.1.3.3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	190
Resistance	4.4.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	190
40 Foot Drop	4.6.1	X																			6
6 Foot *Drop	4.6.2		X																		6
Shock	4.6.3			X								X	X	X	X	X	X	X	X	X	38
Vibration	4.6.4				X							X	X	X	X	X	X	X	X	X	38
Temperature-Shock/Humidity/ Altitude	4.6.5					X															20
Cookoff	4.6.6.1						X														20
High Temperature Exposure	4.6.6.2							X													20
Salt Fog	4.6.7								X												20
Radiographic	4.1.2.2		X	X	X	X						X	X	X	X	X	X	X	X	X	84
Resistance	4.4.2		X	X	X	X		X	X			X	X	X	X	X	X	X	X	X	124
Leakage	4.1.2.3		X	X	X	X						X	X	X	X	X	X	X	X	X	84
Static Discharge	4.4.3.2		X	X	X	X		X	X			X	X	X	X	X	X	X	X	X	124
Resistance	4.4.2		X	X	X	X		X	X			X	X	X	X	X	X	X	X	X	124
Power Current or Stimulus 70°F	4.4.3.1 or 4.4.5.1		X	X	X	X			X			X	X	X	X	X	X	X	X	X	104
Power Current or Parameters 225°F	4.4.3.1 or 4.4.5.1							X		X											40
Resistance	4.4.2		X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	144
Min. 50 Milli sec. All-Fire 70°F	4.4.4		X	X	X				X			X			X			X			72
Min. 50 Milli sec. All-Fire –65°F	4.4.6					X					X		X			X			X		46
Min. 50 Milli sec. All-Fire -200°F	4.7							X		X				X			X			X	46

*Reference MIL-I-23659

c. Pre-production Design and Quality Control. The production system should be reviewed to ensure the inspection system that is required by 14 CFR part 21 is in place. The applicant should ensure that the intent of the cartridge design and development, qualified baseline, and quality aspects are maintained throughout the production life cycle. (Reference §§ 21.1, 21.143. 21.303 and FAA Order 8110.42A).

(1) Manufacturing Processes. The manufacturing processes that should be addressed are identified and described below:

(a) Component Manufacturer or Procurement. Cartridge components should be manufactured or procured from a qualified source by a documented and controlled system that provides closed loop controls to ensure material acceptability. The seal in the cartridge body (header assembly) is one of these critical components. Poor seals may result in failure as the header pins could be explosively dislodged from the cartridge, thereby leaking agent through the cartridge, backshell, or allowing air/moisture contamination of the pyrotechnic mixture.

(b) Bonding Assemblies. Bonding of the assemblies is critical to ensure the cartridge meets all electrical requirements. Failure to achieve complete and proper bonded assemblies may cause failure in dielectric strength, insulation resistance and/or electrostatic discharge capability. This may result in inadvertent firing during electrical surges such as lightning or may result in failure to fire if the cartridge is electrically shorted. Bonding processes include but are not limited to:

1 Proper mix ratio definition.

2 Cure temperature and time definition.

3 Cleanliness of bonded surfaces definition.

4 Coverage of bonded surfaces definition.

5 Bridgewire material selection.

(c) Bridgewire Welding. Bridgewire welding is critical to ensure that the proper electrical energy is transferred to the explosive material. This is achieved through the bridgewire. Typically, the bridgewire is resistance welded to the header pins and is process sensitive. Poor bridgewire welds may result in the cartridge failing to fire as the bridge circuit may open during normal temperature cycling, shock and vibration. Welding parameters include but are not limited to:

1 Length of the bridgewire.

2 Location of the bridgewire weld on the header pins.

3 Strength of the bridgewire welds.

4 Resistance values.

5 Bridgewire material.

(d) Powder Preparation, Critical processes should be controlled by documented procedures. These procedures should address handling safety, ingredient consistence, and assure consistency from lot to lot. Each powder blend is characterized and tested for performance and accepted prior to use in production cartridges. Typically, testing includes caloric content, particle size, thermal analysis, and performance analysis. Steps include but are not limited to:

1 Use of controlled and approved procedures.

2 Acceptance testing of powder prior to use in production cartridges.

3 Documentation and approval of raw materials.

4 Storing and handling.

5 Verification of moisture content.

(e) Powder-loading. Powder loading is critical to the functional performance of the cartridge. Moisture content, hygroscopic capability and volatility of the powder should be verified to ensure proper ignition and output of the explosive. Proper density of the powder should be achieved to ensure all-fire and no-tire capability. Failure to ensure moisture and volatility content and proper pack density will typically result in failure to fire or inadvertent firing by stray voltages. Processes include but are not limited to:

1 Control process environment.

2 Control consolidation force of the explosive into the cartridge.

3 Control the length of time the consolidation force is applied.

4 Control the accuracy of the powder quantity to be loaded.

(f) Hermetic Seal Process. Sealing of the cartridge by a hermetic seal is to ensure the cartridge meets the prescribed life requirements. Failure to achieve a hermetic seal will reduce life as the explosive degrades through normal environment conditions. The integrity should be verified by testing 100% for leakage (e.g., 1 x 10^{-6} scc/sec of helium at one atmosphere).

(g) No deviation to the approved design at any level of assembly should be allowed, unless evaluated under a process accepted by the Administrator.

d. Quality Verification. To adequately validate the cartridge design, or changes to cartridge design, manufacture or processes, cartridge testing should encompass the entire spectrum of criteria from cartridge design, development, qualification and production. The performance elements of the cartridge at the firex system level that are typically used to develop the test and validation methods are:

(1) Design Development. During development, the cartridge design requirements are dictated by the firex system performance requirements. These results can be correlated with other non-system level function tests (e.g., gas flow, function time and environments) and are used to determine how to test the cartridge (reference matrix, table 1).

(2) Design Change Control. A process for design changes should be defined and accomplished in a method acceptable to the Administrator. All design changes should be correlated with the firex system performance requirements.

(3) Design Qualification & Validation. System qualification testing should ensure that the cartridge:

(a) Performs the required functions at the system level.

(b) Can effectively open the burst disc, ensuring correct agent flow under all operating conditions.

(c) Does not cause any peripheral degradation of the firex system as the result of the explosive event occurring.

(4) Testing. During cartridge qualification and validation, the applicant should perform system level tests to demonstrate the capability of a cartridge design to meet the burst disc rupture requirements. Forty tests are a typical number of tests at the system level per MIL-C-22284. Cartridge qualification and validation also involve non-system level testing where key design elements are evaluated (reference table 1). This combined test series establishes baseline reliability and performance parameters.

Once the design is validated, these results may be correlated with other non-system level function tests (e.g., dent tests, lead extrusion or pressure-time tests) to develop suitable production lot acceptance test criteria. Such testing can effectively indicate manufacturing process control issues in a validated design. However, they should not be used to demonstrate the suitability of a new design for a given system. Using non-system level test methods to demonstrate similar performance of a new design to a qualified design does not validate the suitability of a new design to work properly in an installed firex system. Use of non-system level tests and analysis should be substantiated to show equivalence as installed on the actual firex system.

(5) Production Lot Acceptance Testing. Cartridge sample lot acceptance testing is a means of assessing the manufacturing process to ensure that nothing has changed which might have affected cartridge performance. After cartridge qualification, test methods and criteria are developed to ensure production cartridges conform to the performance requirements of the qualified design. This demonstrates that the production cartridges have not changed with respect to the qualified design.

(a) Bridgewire Resistance on 100% of the lot.

(b) Dielectric Strength on 100% of the lot.

(c) Insulation Resistance on 100% of the lot.

(d) Leakage on 100% of the lot.

(e) Radiographic on 100% of the lot.

(f) Electrostatic Discharge on 100% of the lot (if applicable).

(g) No-fire on a lot sample.

(h) All-fire on a lot sample.

(i) Functional Performance on a lot sample.

e. Service Life Issues. The firex system is a safety system that is subjected to an aircraft flight environment that consists of exposure to repeated cycles of temperature, altitude and vibration. This system remains dormant until it is needed, and should perform flawlessly. One cannot afford to compromise on the long term quality when approving new, modified or replacement cartridges. For example, cracked seals and poor welds can be patched with potting to pass helium leak tests during production lot acceptance. However, this low quality fix may not survive the entire rated service life. Repeated cycles of temperature and altitude can force moisture into the explosive charges. As previously discussed, this can cause cartridge failure resulting in non-actuation of the firex system thereby compromising safety.

The applicant should identify the method to validate the service life proposed. Accelerated life testing should reference MIL STD 1576 Table IV methodology or equivalent. This validation should be completed prior to initial approval. The aircraft installation environment should be evaluated with respect to the service life test plan to ensure compatibility with the proposed service life of the cartridge.

f. Final Approval Process. The overall review should address all of the following items:

(1) Applicant's Data Package. The applicant's data package should contain the following information:

(a) An overall certification plan.

(b) Detailed drawings on the proposed item.

(c) Manufacturing/quality procedures and processes.

(d) Engineering Change Orders for the proposed item.

(e) Statement of differences between the proposed item and the baseline item.

(f) A plan to address the testing specified in Table 1.

(g) All proposed component level tests on the proposed item.

(h) Proposed qualification test plan on the applicants and PAH items.

(i) Identification of proposed system level tests to be performed.

(j) Functional test methods to be used on both items with an explanation of the pass/fail criteria.

(k) Proposed life testing.

(l) Production quality screening plan (lot acceptance).

(2) Final Qualification. The qualification is usually performed by one of the following methods:

(a) Test. The test method is to fire the cartridge in charged bottles under operational conditions. Typically, the firex system level tests are performed during development and qualification of a new design, and should establish system performance of replacement parts.

(b) Approval by Identicality or Test & Computation (reference FAA Order 8 110.42A). The following items should be addressed:

1 Engineering drawings of the proposed cartridge. These drawings should contain adequate detailed information to accurately define the cartridge assembly and its components, item by item, to show identicality to approved parts. Any significant differences with the original approved cartridges should be approved under the test and computation method. Examples of significant differences are: charge material changes, loading changes, process changes, changes in supplier/manufacturer, and physical configuration differences.

2 For parts determined to be critical and/or life-limited, the FAA may require the applicant to perform inspections and tests, and submit the results to the FAA. The test results are necessary to show airworthiness of parts produced in conformity with the proposed design in order to obtain design approval. If the application is based upon identicality, submit test results that demonstrate that the airworthiness of the part (as originally approved, is not altered by the manufacturing

methods and processes performed by the applicant. If the application is based upon test and computation, or STC, submit both design and manufacturing test results.

3 It is recommended that all sections of this AC be addressed by the applicant in a certification plan and that the certification plan be approved by the FAA prior to commencing qualification activities.

4 The applicant should address any aspect that might degrade:

(aa) Safety.

(bb) Performance.

(cc) Soundness of mechanical design.

(dd) Resistance to environment.

(ee) Service life.

5 All cartridges are considered critical components and therefore performance testing requirements should be defined and testing should be required.

6 All subsequent changes to the design, including process changes, after initial approval, should be considered major changes unless concurrence with the cognizant ACO has been obtained. No parts should be shipped which are of any major change configuration prior to FAA approval of that change. Parts shipped prior to FAA approval of any major change may be subject to the Suspected Unapproved Parts reporting requirements of FAA Order 8 120.1 OA.

(c) Identicality by Licensing Agreement. Section 21.303 requires parts manufactured by someone other than the original approval manufacturer (e.g., PC Holder) to establish a Fabrication Inspection System (FIS) and review with the ACO/MIDO as to what additional testing may be required in accordance with Order 8110.42A, paragraph 9.c.(3).

8. PRECISION BURST DISC.

[Reserved]

9. FILL/CHANGE FITTING.

[Reserved]

10. PRESSURE INDICATOR.

[Reserved]

11. DISCHARGE HEAD ASSEMBLY.

[Reserved]

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